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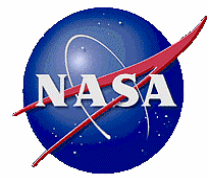

Return on Investment for Software IV&V

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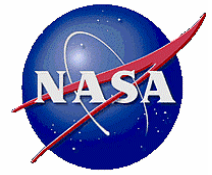
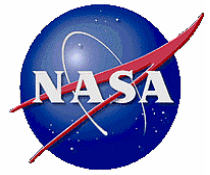
Overview



- Overview of IV&V ROI
- Direct ROI computation
- Indirect ROI computation
- Predicting ROI
- Conclusions & Future Work

IV&V ROI Motivation



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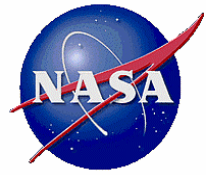
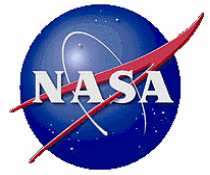
- Important measure of IV&V project value
  - Helps to understand overall IV&V effectiveness
  - Comparison to similar projects
  - Directly quantify value added
- Prevalence of ROI references in other research
  - Most HICSS papers indicated need for ROI computation
- OMB-mandated for some U.S. government-sponsored projects
- Model should allow ROI prediction for candidate projects
- Model should allow ROI computation for completed projects

IV&V ROI



- Many benefits of IV&V difficult to quantify
  - Most cause cost avoidance
    - Reduced development cost
    - Reduced operational cost
    - Increased likelihood of mission success
  - In many cases, actual cost of an undiscovered error can't be predicted
    - Depends on whether error is manifest in operations
    - Depends on situation when error is manifest

ROI Definitions



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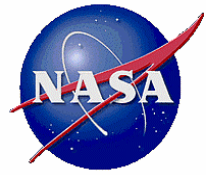
- ROI (benefit/cost ratio)

$$\text{ROI} = \frac{\text{Cost saved due to IV\&V}}{\text{Cost of IV\&V}}$$

- Direct ROI – result of reduced development cost
- Indirect ROI
  - Improved quality
  - Reduced risk
  - Improved safety
  - Increased confidence in product
- ROI model developed for software IV&V
  - Methodology directly applicable to other systems engineering disciplines

Direct ROI Computation



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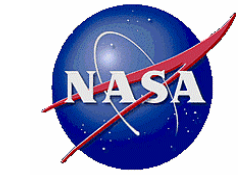
$$\mathrm{ROI} = \frac{C_x - C_i}{C_{IVV}}$$

- C_i – total development cost actually experienced
- C_{IVV} – cost of IV&V
- C_x – expected development cost without IV&V
  - Assume developer would have discovered all IV&V-discovered issues
  - Same probability distribution developer exhibited in remaining phases
  - Cost-to-fix escalation based on published data

Direct ROI Model Structure



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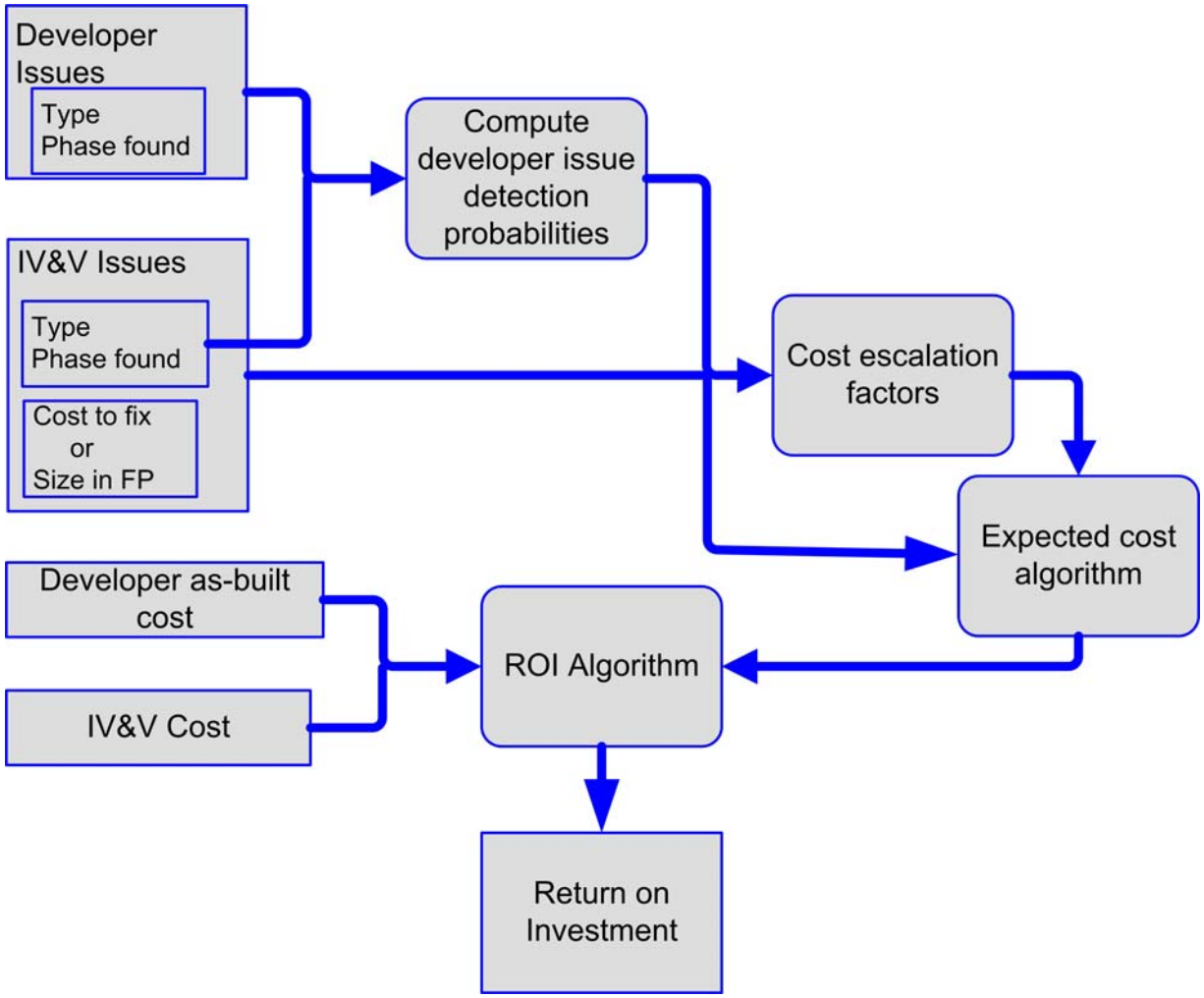
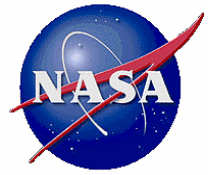


Cost-to-Fix Escalation



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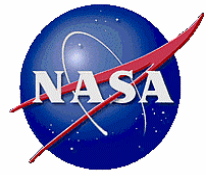
- Cost to fix a defect increases as project progresses
- Cost escalation model based on weighted average of published results
  - Weighting accounted for
    - Relevance of study to NASA mission-critical software
    - Credibility of results
    - Size of study
- Most data for requirements defects
- The data available indicate that similar trends occur for other types of defects (design, code, test, integration)
- A sensitivity study demonstrated that model is relatively insensitive to variations in the cost-to-fix escalation factors

Cost-to-fix Escalation Factors



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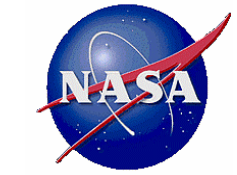
Issue type	Phase issue found					
	Requirements	Design	Code	Test	Int	Ops
Requirements	1	5	10	50	130	368
Design		1	2	10	26	74
Code			1	5	13	37
Test				1	3	7
Integration					1	3

Case Study Results



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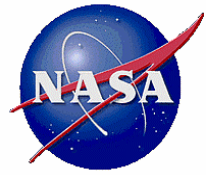
- Four mission-critical NASA projects
  - Mission control center software
  - Interplanetary spacecraft
  - Next-generation experimental spacecraft
  - Manned spacecraft
- Direct ROI computed for each project

Direct ROI Case Study Results



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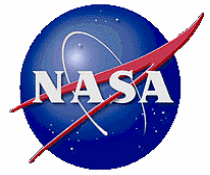
Project	Size (function points)	ROI
A	280	1.59
B	1086	1.21
C	110	5.53
D	2268	10.1

Indirect ROI



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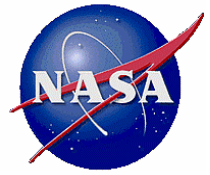
- Many important benefits difficult to quantify
- Candidate list of 84 indirect benefits refined to four that can be quantified credibly
  - Improved testing
  - Reduced high-criticality errors
  - Requirements clarification
  - Reduced error leakage to operations
- Developed method to compute each

Predicting ROI



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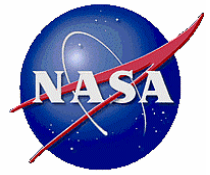
- Tool to predict ROI of IV&V will be very useful
  - Assist in allocating resources for greatest benefit
  - Model-based effectiveness metric
- Products of predictive model are inputs to direct ROI algorithm – issue discovery rates
- Predictive model must be based on information available (at least estimated) early in lifecycle

Predictive Techniques Considered



- Capture-Recapture
  - Based on biological models for counting animals
  - Different techniques can be expected to find different defects
  - Rejected because studies show not reliable for software
- CoQUALMO
  - Uses appealing defect flow model
  - Rejected because not calibrated & would require many (hundreds) studies to calibrate
- Bayesian Belief Networks
  - Exploits expert opinion and available data optimally
  - Calibration to case study data relatively straightforward
  - Appeared extensible to full predictive model (Fenton)
  - Accepted because of success of other researchers in BBN modeling of software defect density

BBN Node

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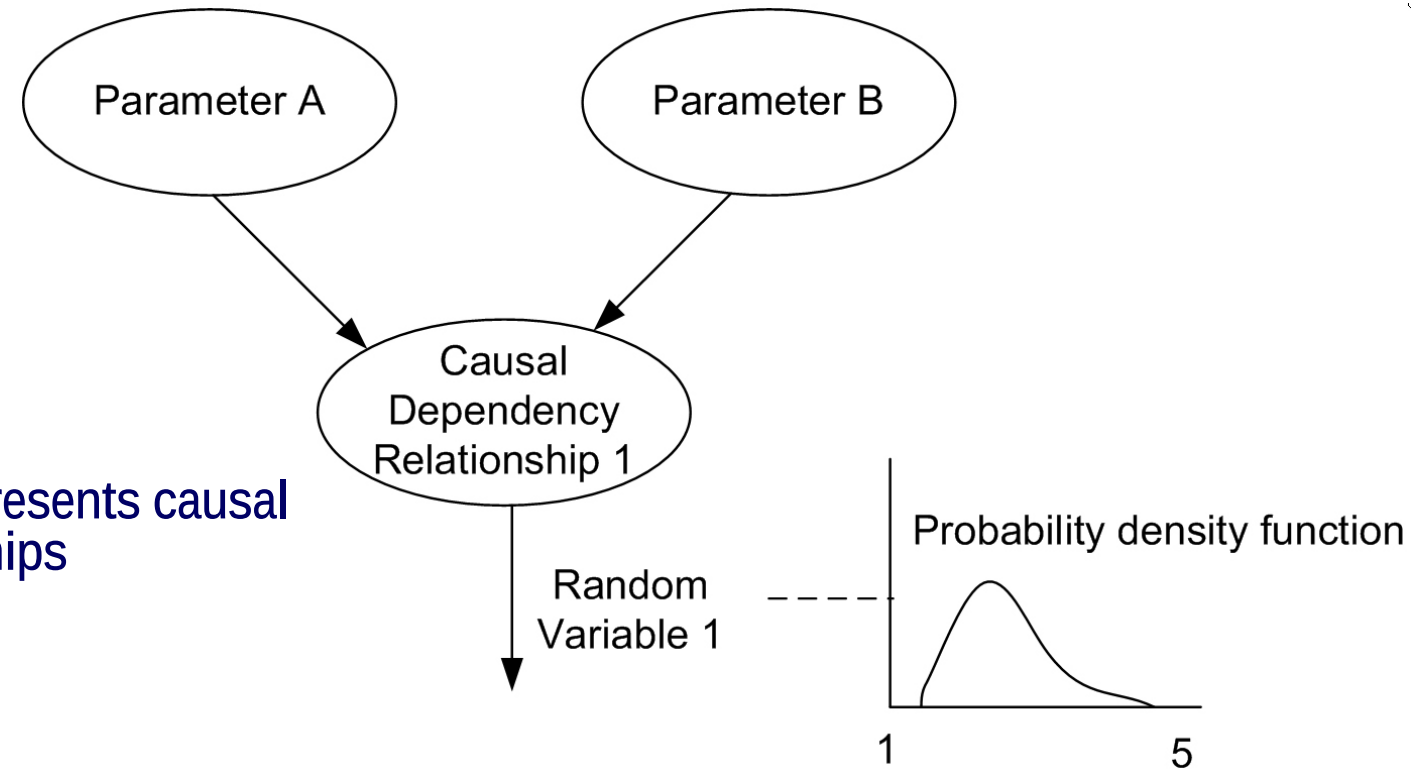
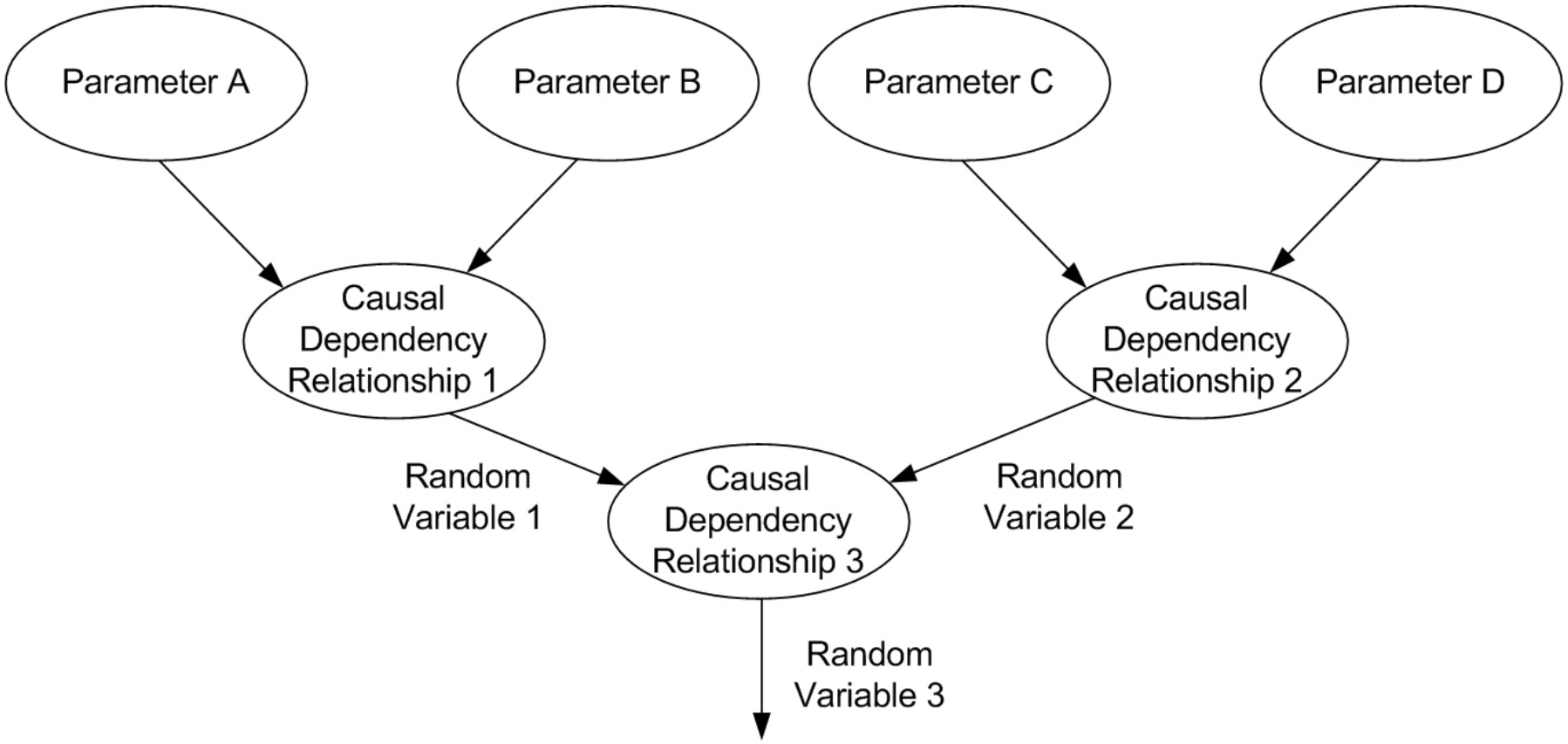


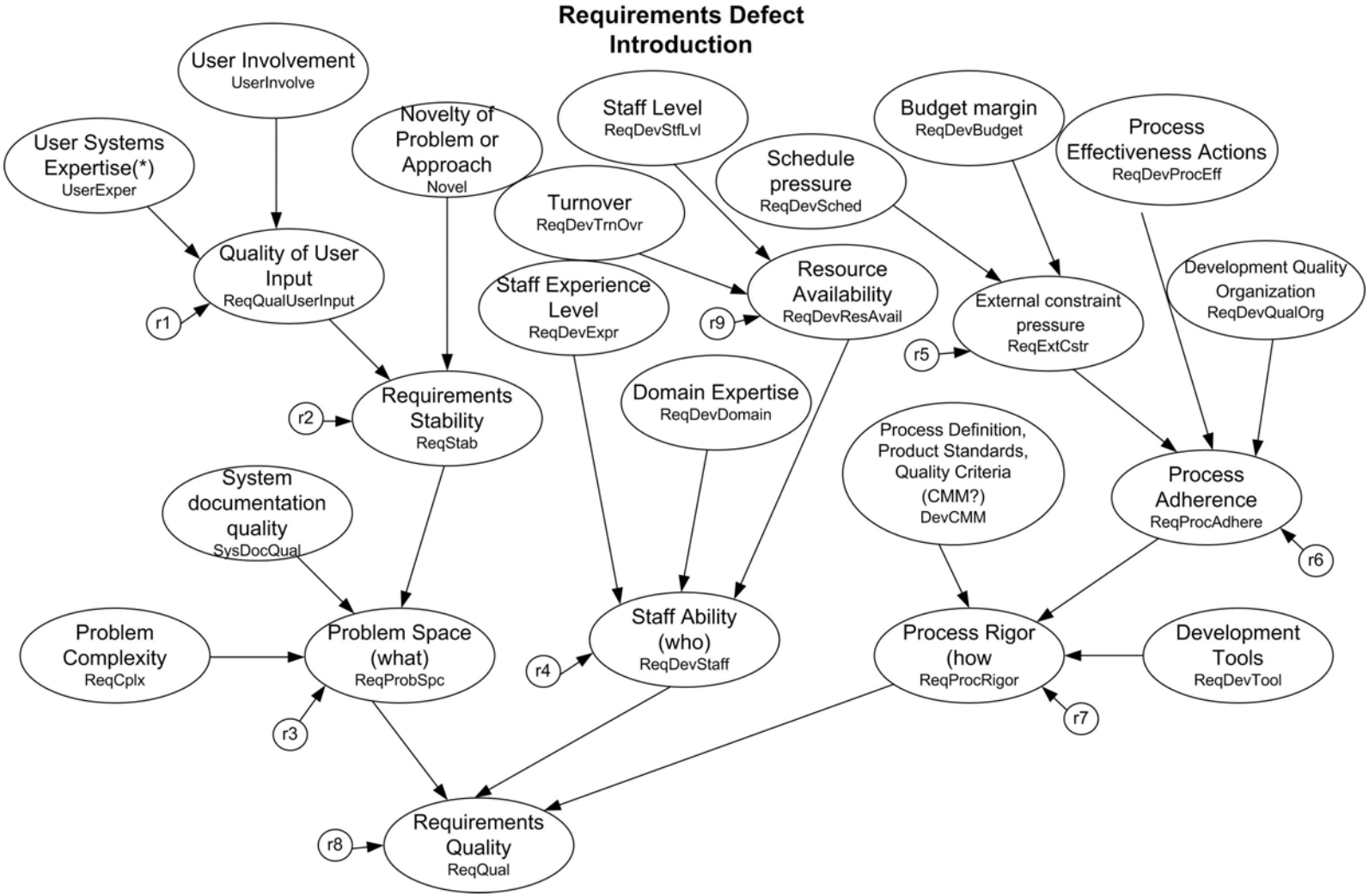
Node represents causal relationships

Node output is a random variable with a probability density function that depends on the node inputs

Cascaded Nodes



Requirements Quality BBN



Developer Defect Discovery BBN

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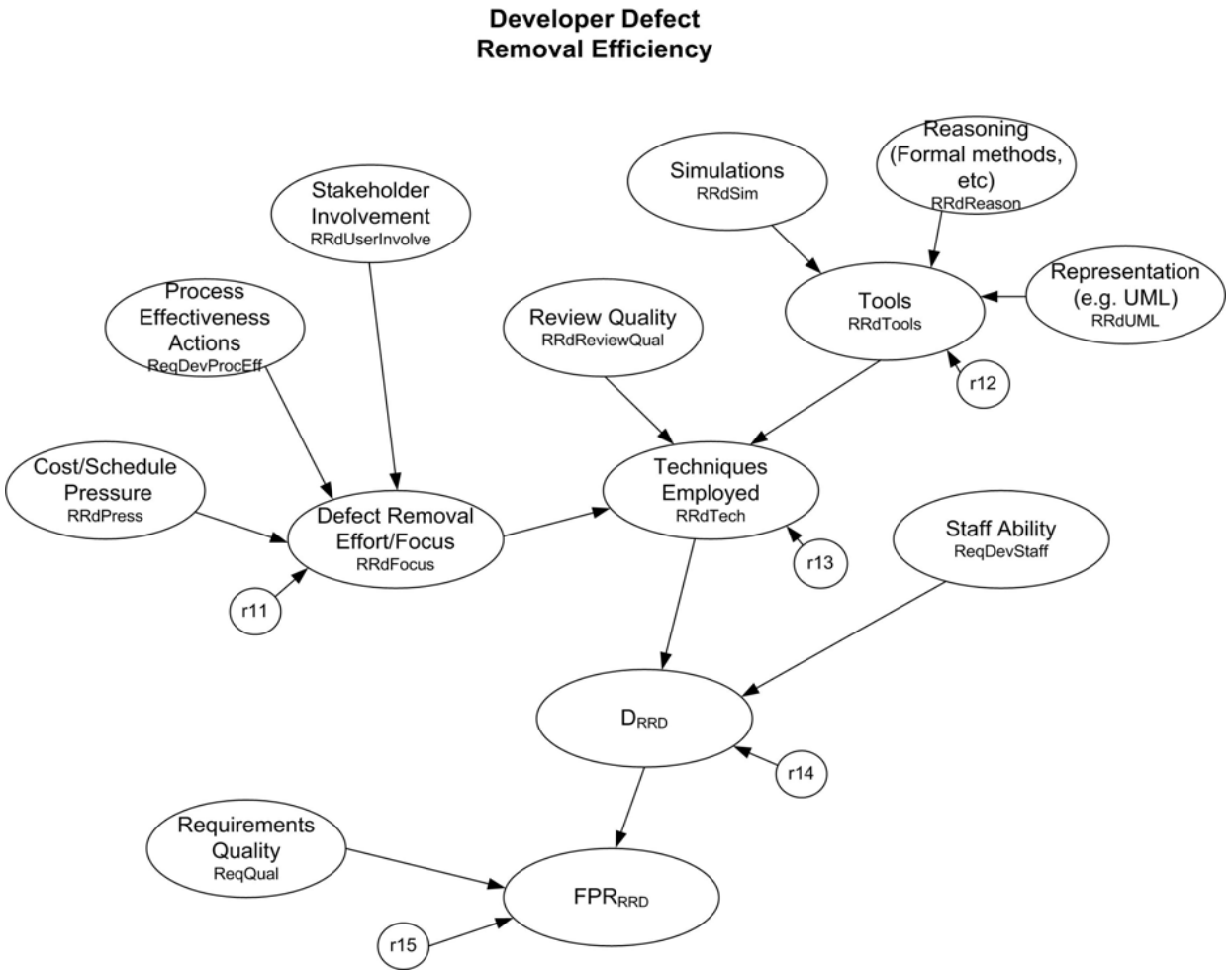
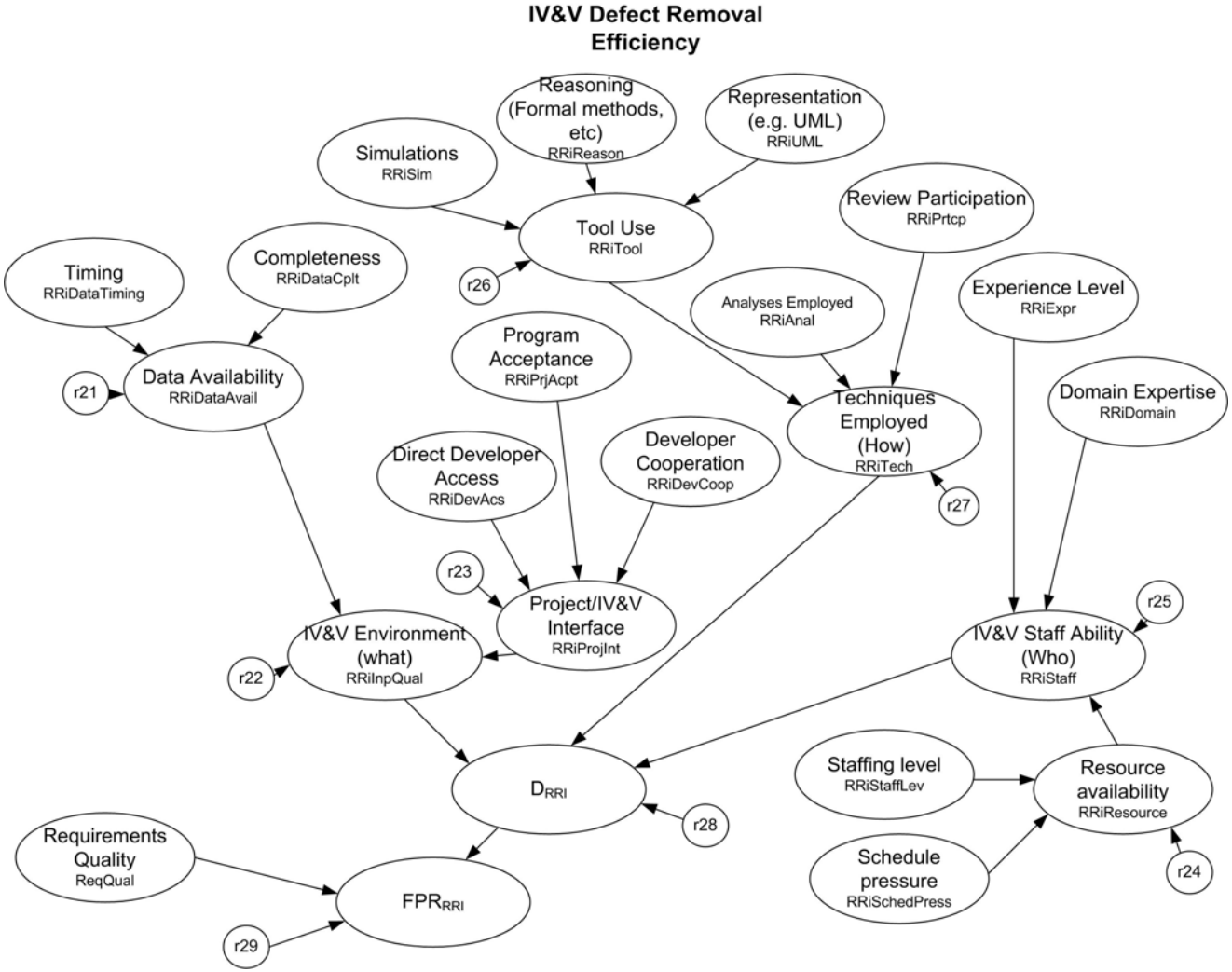
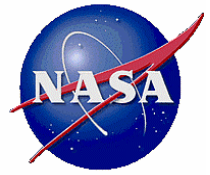


IV&V Defect Discovery BBN

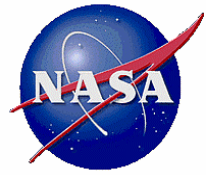


BBN Output



- Objective is set of inputs for direct ROI model
- Developer and IV&V budgets generally available
- In-phase issue discovery profiles from BBN
  - Function point ratio (FPR) selected
  - Ratio of issue size to total project function points
  - Function points can be estimated early in the project
  - Product of FPR and total function points is the required input

Leakage Model



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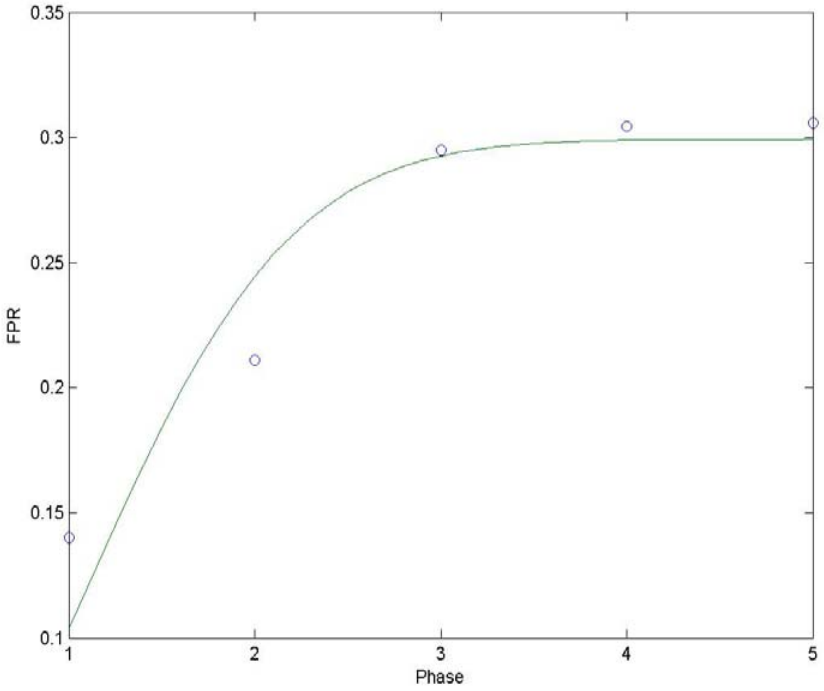
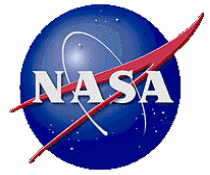
- BBN predicts in-phase issue detection
- Rayleigh curve approximates leakage from originating phase to subsequent phases
- Supported by extensive literature and consistent with case study results
- Calibrated to case study data
- Shift curve for phases later than requirements

Example Rayleigh Curve

- Circles are actual cumulative FPR per phase
- Curve is calibrated Rayleigh approximation to cumulative FPR per phase
- FPR values are weighted using cost escalation model



Conclusions



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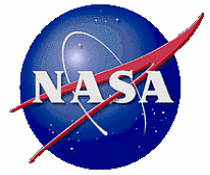
- Direct ROI methodology provides a credible means to compute ROI for IV&V
- Adding indirect ROI more accurate, but difficult to compute
- Predictive ROI model is promising
  - Uses information available early in lifecycle
  - Preliminary calibration produced consistent results

Future Work



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- Produce production-quality predictive ROI model
- Perform additional case studies to improve calibration of BBN output to FPR